

Reinhold Environmental Ltd.



2009 APC Round Table & Expo Presentation

July 12-14, 2009, in The Woodlands, TX

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“SBS Injection – Recent Operating Experience & Advancements”

2009 APC/PCUG Conference
July 12-16, 2009
The Woodlands, Texas



Agenda

- SBS Injection™ Technology Overview
- “Pre-SCR” Injection Concept & Benefits
- Pre-SCR Application at Gibson
 - System description & configuration
 - Test results
 - Future operation & testing
- Liquid Injection – Advantages & Challenges

SBS Technology Description

- Patented Technology
 - Owned by Codan Development, commercialized by URS
- Reagent Injected via Dual-Fluid Nozzles
 - Sodium-based solutions of soda ash or sodium sulfite
 - Droplets are flash dried to form a fine particulate
 - Particulate selectively reacts with SO_3
- Provides High SO_3 Removal Efficiencies
 - Injection system achieves uniform coverage across the duct
 - Dried particle size range of 1-10 μ
- Product Collected in ESP, FF or Wet Scrubber
- Simple & Reliable Equipment Operation
 - Routine preventative maintenance is essential

12,500 MW Installed on 20 Boilers



Gibson June 2004 – No Treatment

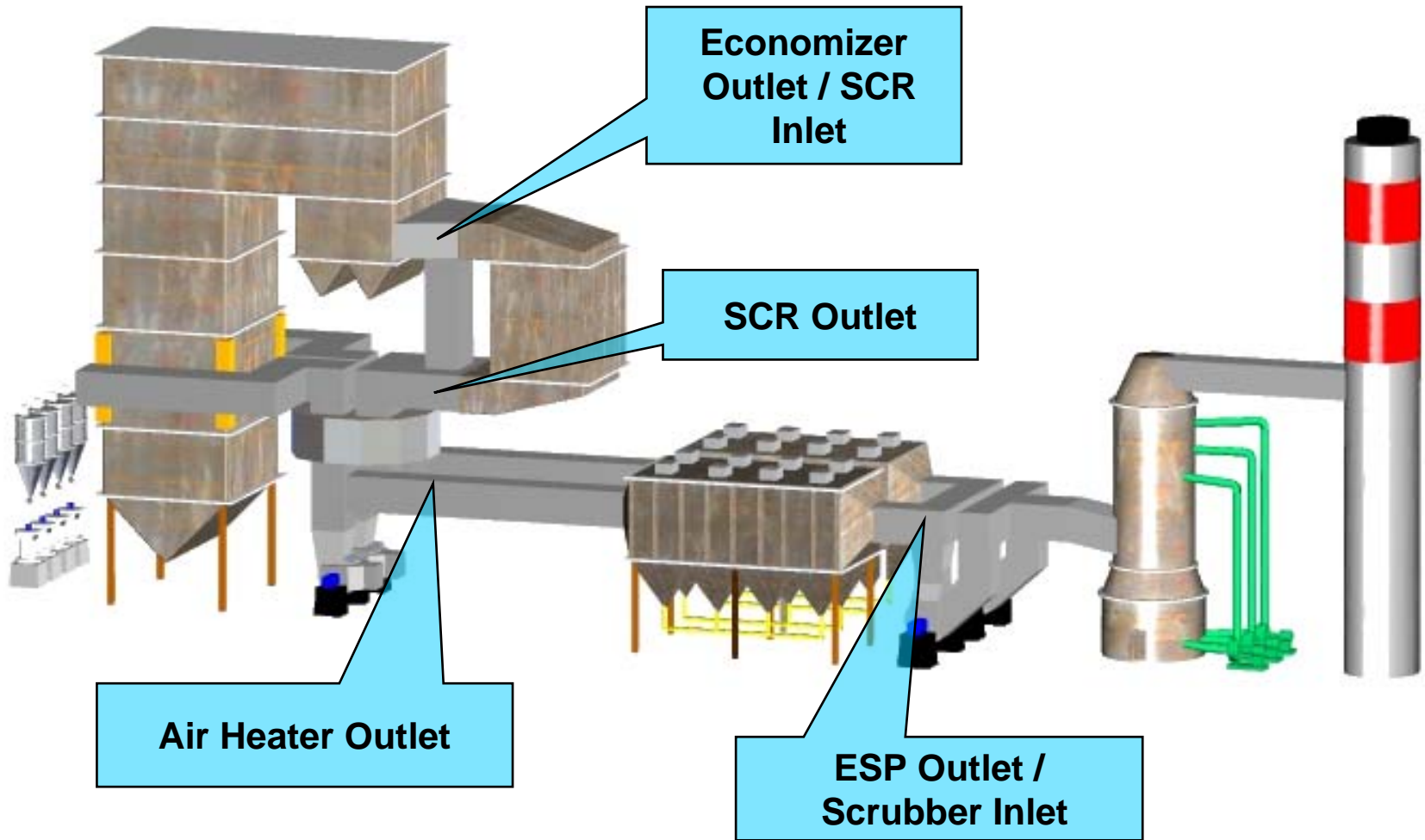


Gibson June 2005 – SBS Injection

Benefits of SO₃ Control

- Opacity Elimination
- Corrosion Reduction
- Co-Removal of Hg, HCl & Se with Fly Ash
- Enhanced Heat Recovery with CO₂ Reduction
- SCR/SNCR Operating Flexibility
 - Increase NO_x removal efficiency
 - Extend catalyst life
 - Reduce the SCR Minimum Operating Temperature

SBS Injection Locations



Additional “Upstream” Injection Benefits

- More Reliable Injection Lance Operation
 - Faster droplet drying time
 - Less deposition of acid & ash
 - ✖ Corrosion environment is not as severe
 - ✖ Less expensive materials of construction
 - Lower frequency of lance inspection & maintenance

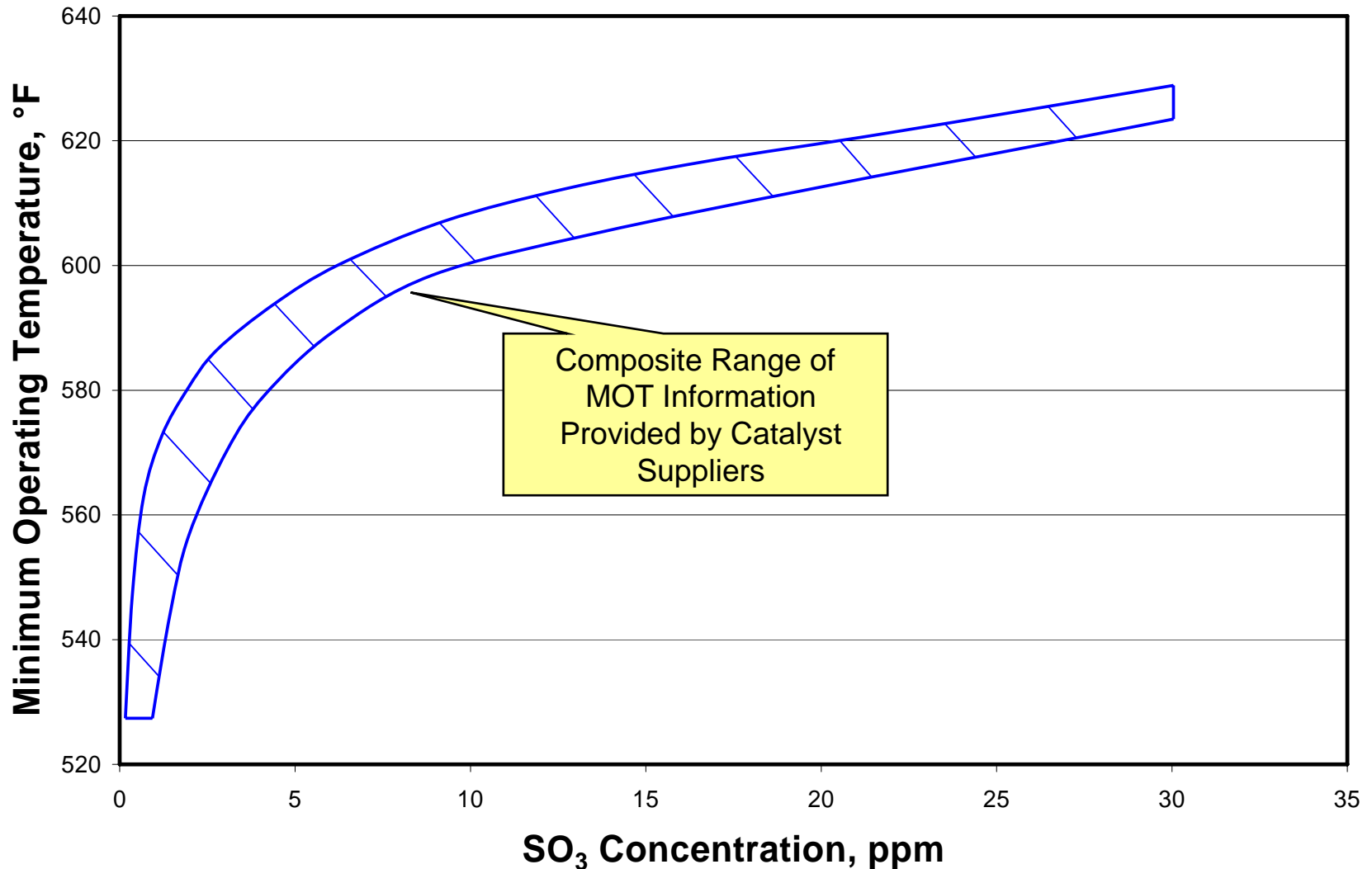
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“Pre-SCR” Injection Benefits

1. Increase the Residence Time for SO_3 Removal
 - Provides the benefits of SO_3 removal upstream of the air heater if a suitable injection location is not available at the SCR outlet
2. Reduce the Minimum Operating Temperature (MOT) within the SCR
 - SO_3 Reacts with NH_3 to form ABS
 - ABS condenses within the catalyst pores
 - Prolonged operation with ABS will plug the catalyst
 - Catalyst suppliers specify an MOT

Minimum Operating Temperature vs SO₃



MOT Management Strategies

- Shut Off Ammonia Flow at Lower Loads
- Restrict Lower-Load Operation
- Raise SCR Temp with Economizer Bypass
- Modify Economizer to Remove Less Heat
- “Burn Off” Condensed ABS
- Fire Lower-Sulfur Coals to Reduce MOT
- Remove SO_3 Ahead of the SCR to Reduce MOT

Pre-SCR Experience to Date

- Pre-SCR R&D
 - Extended catalyst exposure testing at Mansfield
 - Integrated pilot testing at the MRC
- Commercial Applications at Killen & Stuart
 - Killen – Low-dust SCR, two injection locations
 - Stuart – High-dust SCR, injection upstream
- Commercial Demonstration at Gibson
 - Injection upstream of high-dust SCR
 - Unit 5B system in operation since April 2009

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Gibson Unit 5 – Overview

- Nominal 661 MW Foster Wheeler Boiler
 - Dual gas path from split back pass through ESP's
- High Dust SCR
 - 3 layers of catalyst (including a regenerated layer)
 - 85% design NO_x removal efficiency
- Horizontal-Shaft Air Heaters
- Cold-Side ESP's
- URS-Modified Kellogg Horizontal Scrubber
- Bituminous Coal
 - Sulfur levels range from 4-6 lb/MMBtu

Original SBS Injection™ System Design

- SBS Injection™ Installed on All 5 Gibson Units
 - Systems installed in May 2005
 - Installed to mitigate “blue plume” visible emissions
- Reagent Injected Downstream of the APHs
- Operations Overview
 - Switched from sulfite to carbonate reagent in 2005
 - Operated during the ozone season prior to 2009
 - Now operated year-round with the SCR's

Relocated SBS Design for Duct 5B

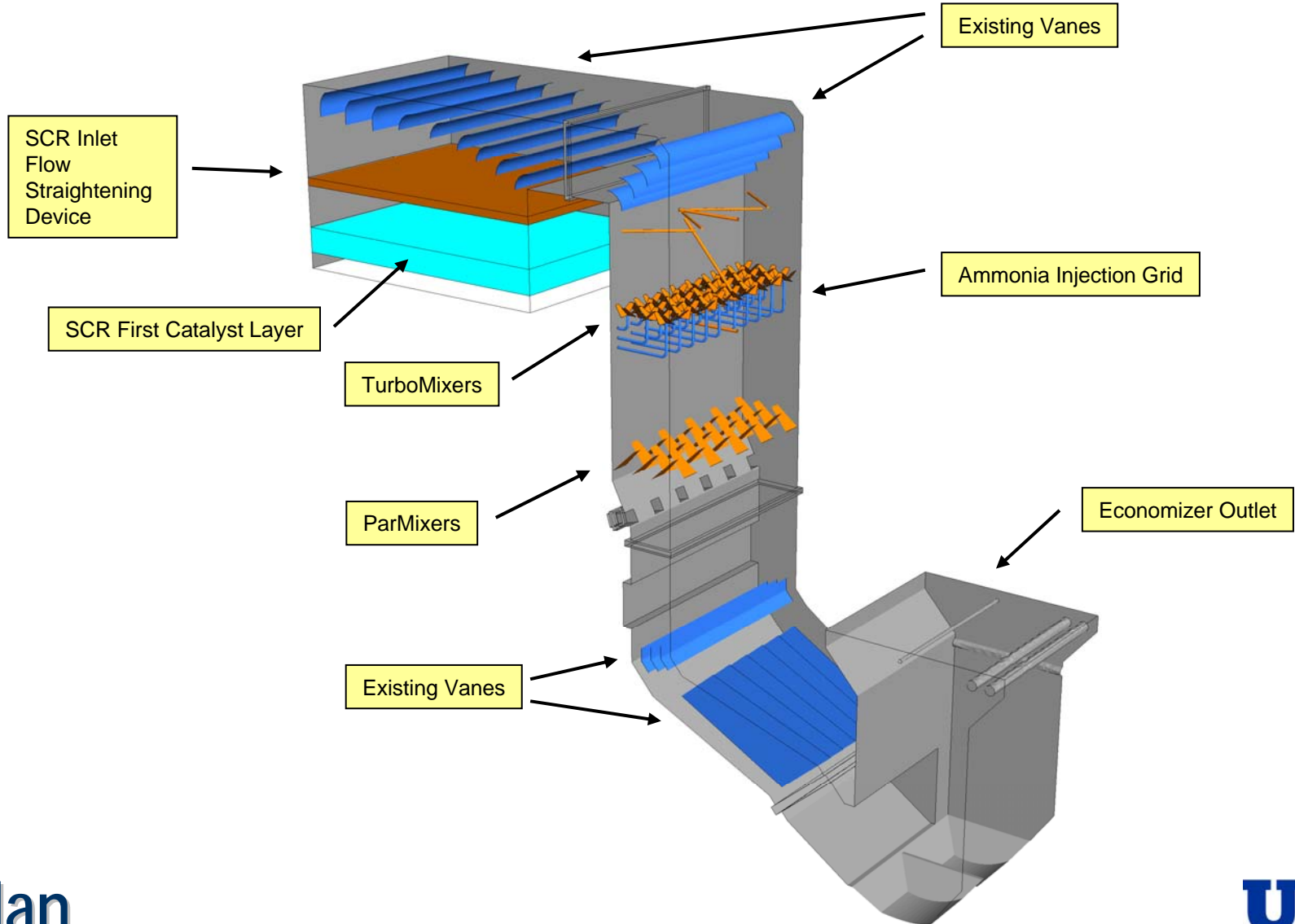
- Injection Moved Upstream of SCR on Duct 5B
 - Primary benefit is improved unit reliability
 - ✗ Reduced air heater fouling with fewer forced outages
 - ✗ Reduced lance maintenance with less duct deposition
 - Potential reductions in operating costs
 - ✗ Reduced NO_x emissions and/or extended catalyst life
 - ✗ Lower load operation with full NO_x reduction capability
 - ✗ Improved unit efficiency

Relocated SBS Design for Duct 5B

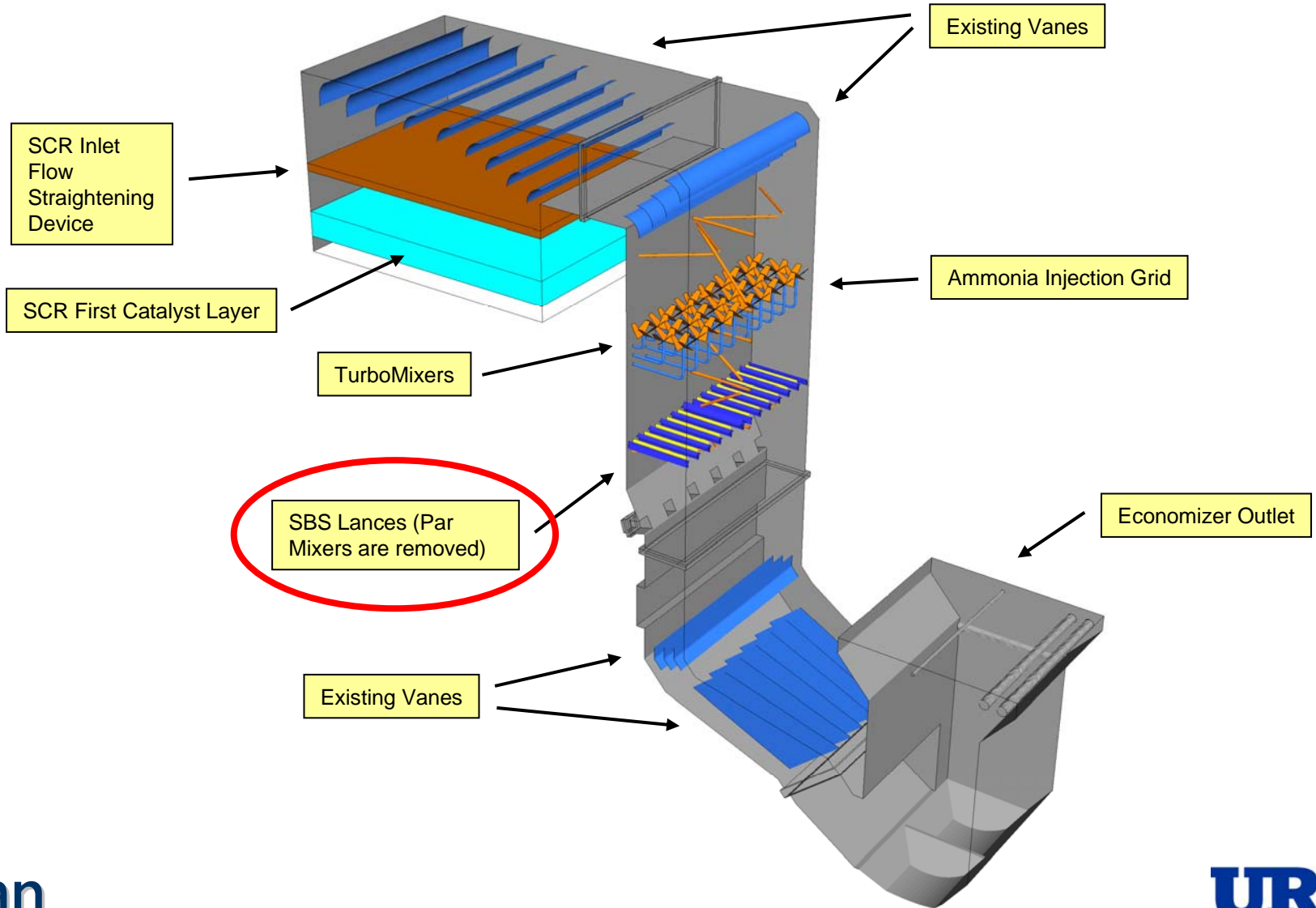
- Project Timeline

- Engineering & injection location selection in 2008
- Equipment relocated in early 2009
- March start-up
- Testing & continuous operation in April 2009
- Duct 5A relocation in progress
- Catalyst sampling & analysis later in the summer

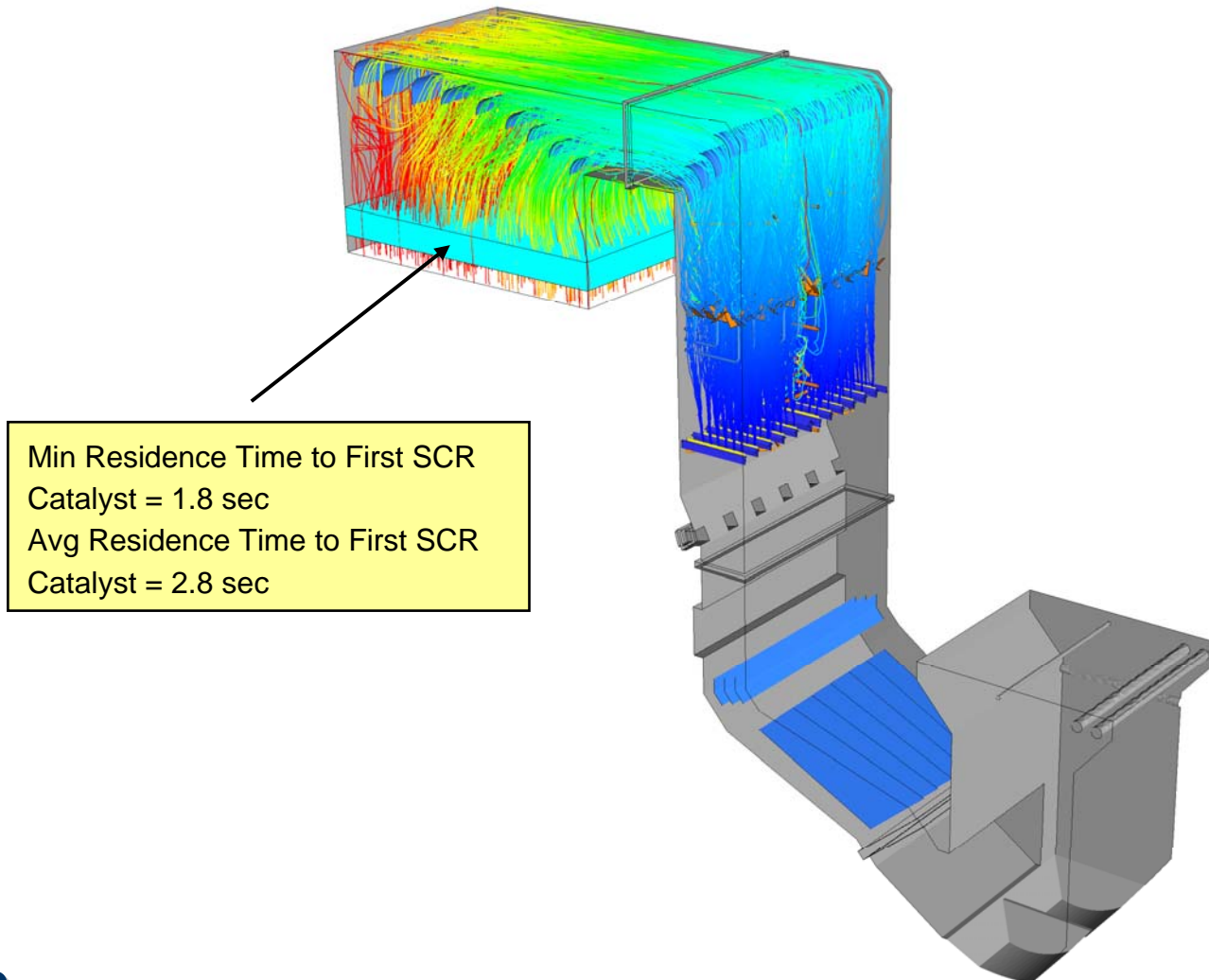
Existing Duct Geometry



Duct Geometry w/SBS



Estimated Residence Time to Catalyst



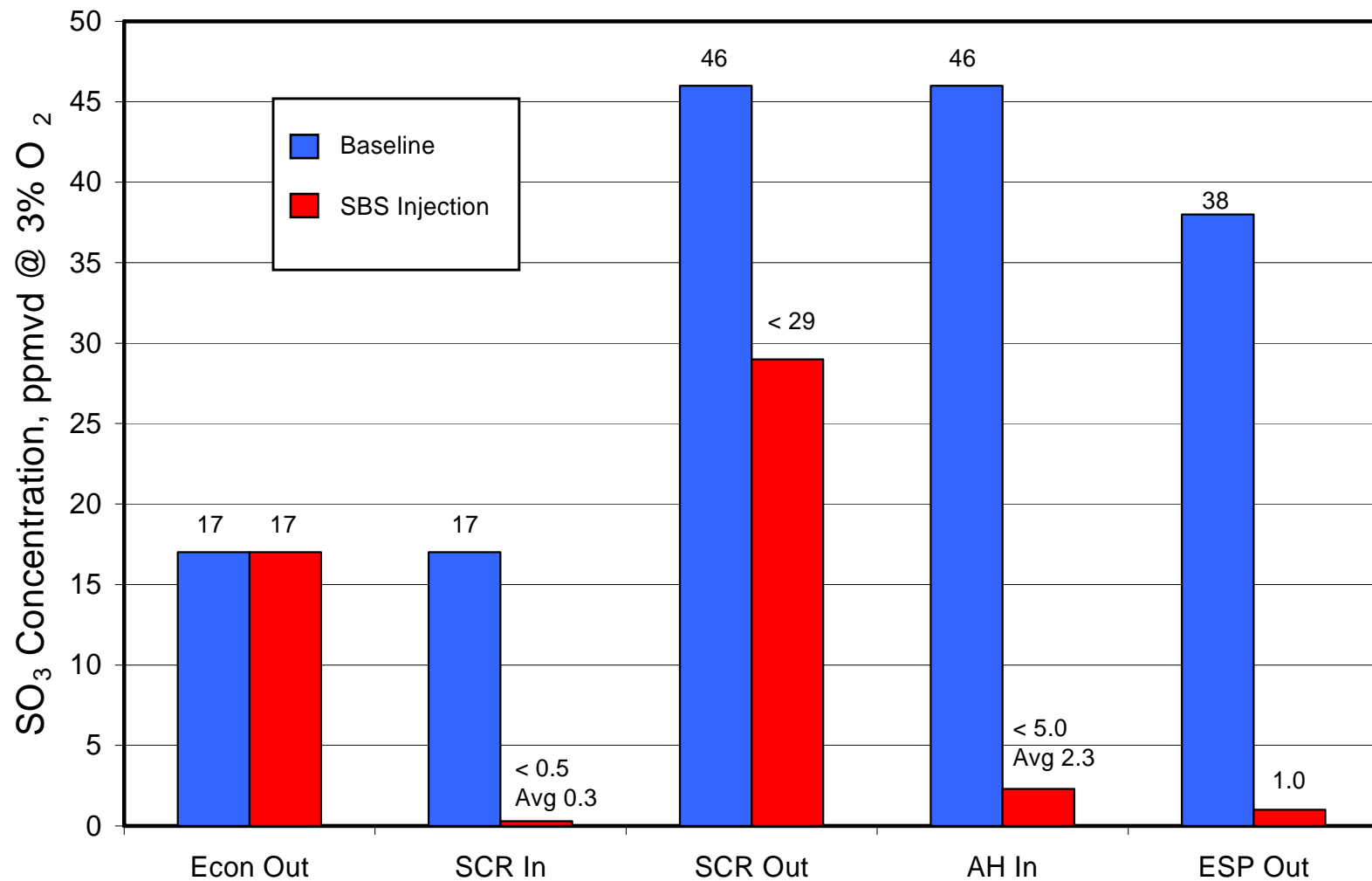




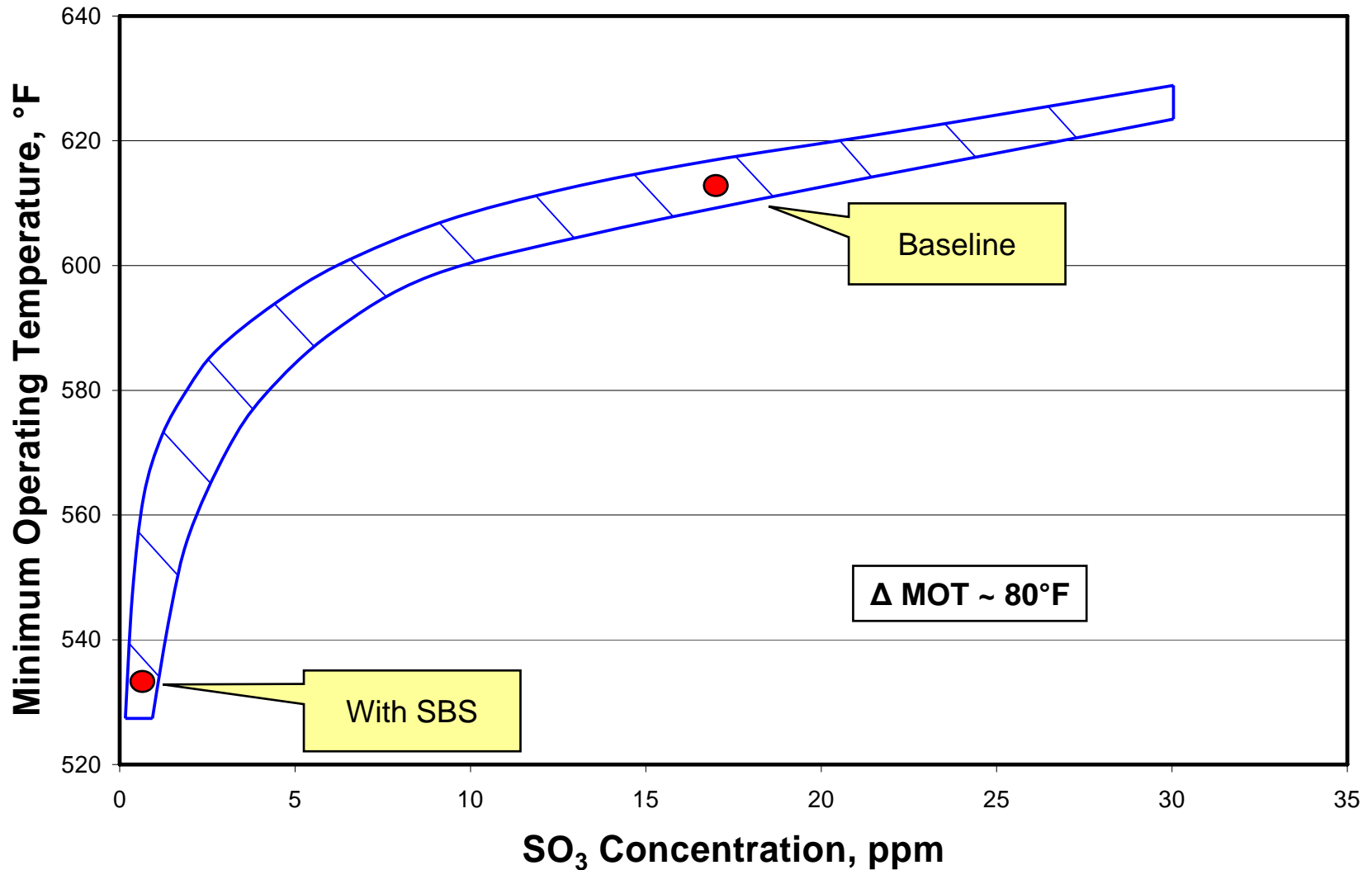
SBS System Testing – April 2009

- Baseline Conditions
 - 2,400 ppm SO₂
 - 17 ppm SO₃ from boiler
 - 46 ppm SO₃ at SCR outlet
 - 38 ppm SO₃ at ESP outlet
- Tested a Wide Range of Reagent Injection Rates
- Measurement Locations on Unit 5B
 - SCR inlet (4 corners just above first catalyst layer)
 - Air heater inlet (4 ports across duct)
 - ESP outlet

SO₃ Profile – At Recommended Conditions



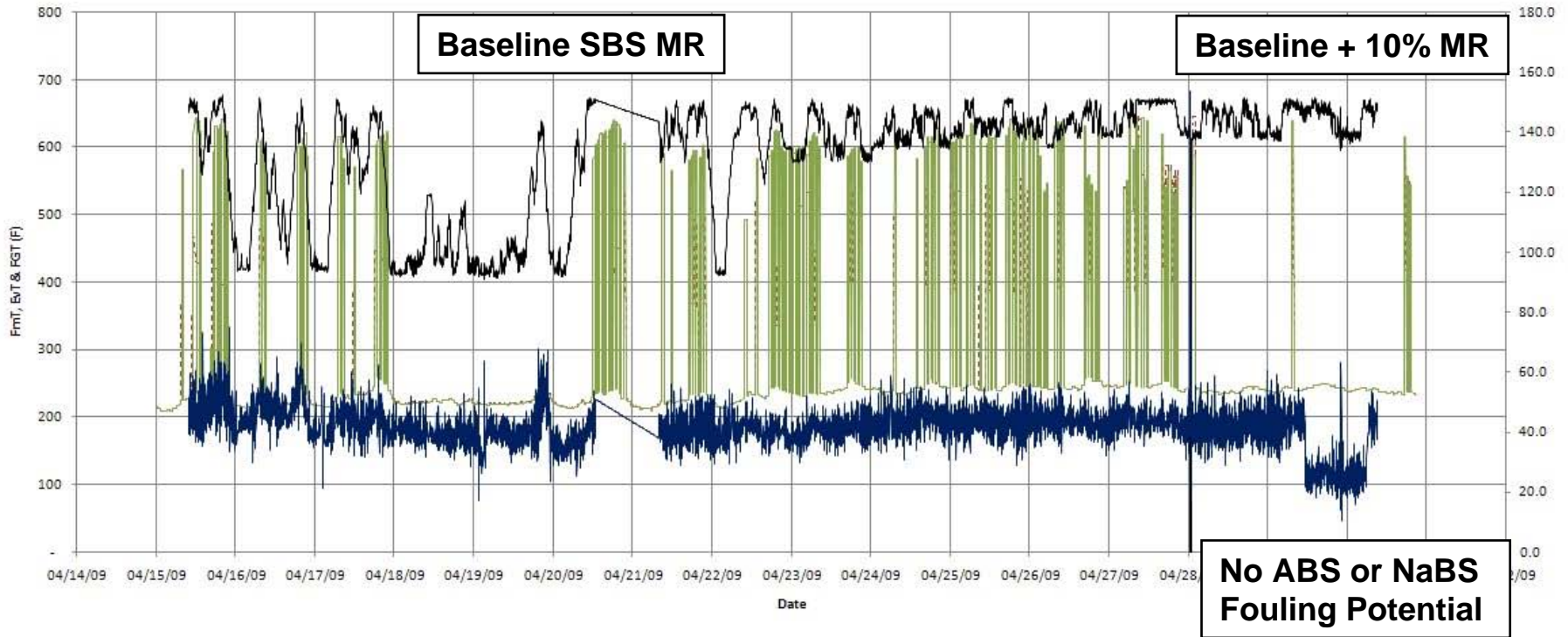
Minimum Operating Temperature vs SO₃



Air Heater Fouling Test

- Breen ABS/SO₃ Probe at Air Heater Inlet
 - Monitoring periods:
 - ✖ Performance test (April 1-3)
 - ✖ Elevated NH₃ feed test (April 9)
 - ✖ Continuous operation (April 15-30)
- Results
 - Baseline injection rate:
 - ✖ Fouling potential noted at full load but not reduced load
 - Baseline +10% injection rate:
 - ✖ No fouling potential noted over load range
 - ✖ No fouling with elevated ammonia slip

Air Heater Fouling Potential

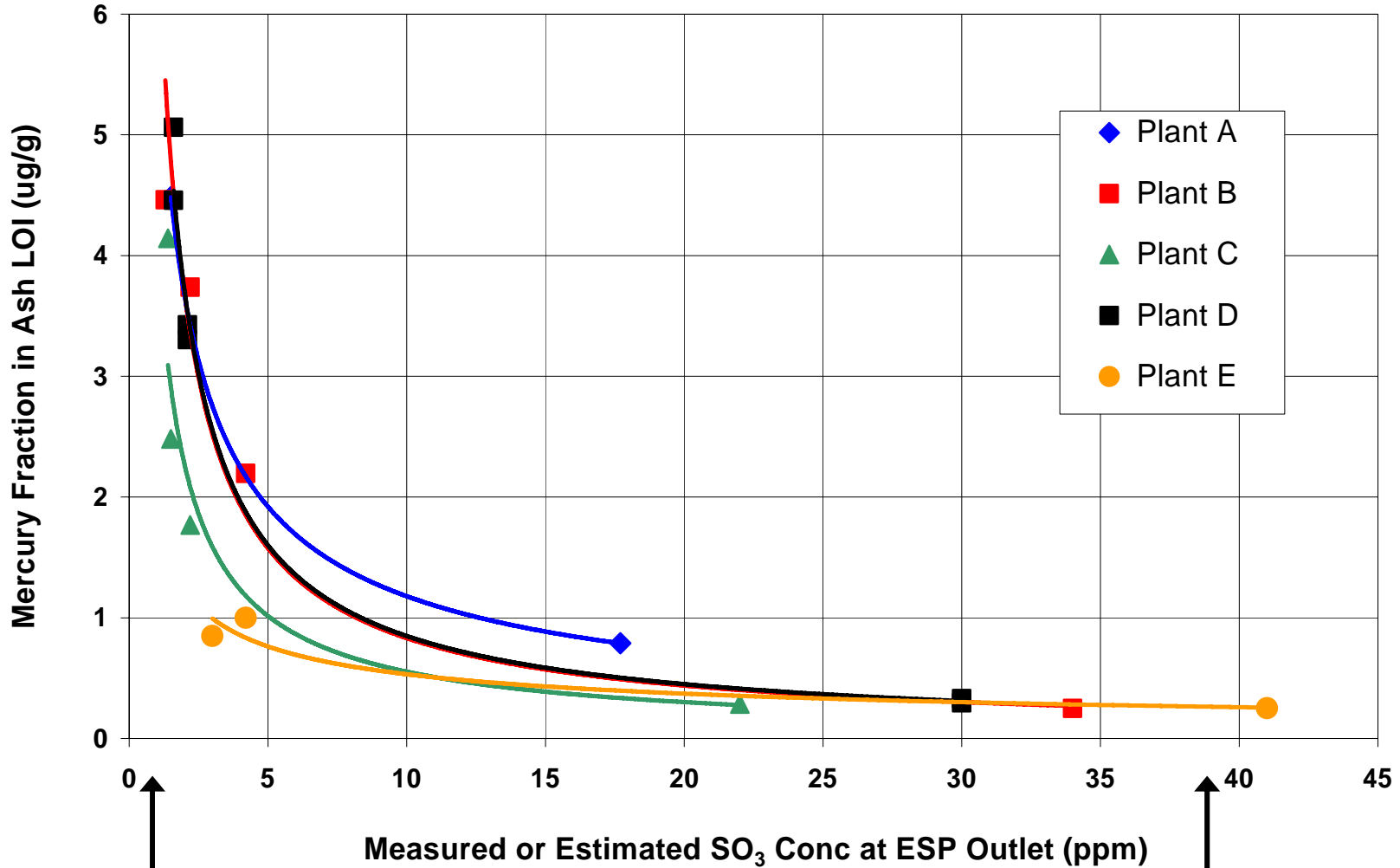


Black Trend = Unit Load (MW)

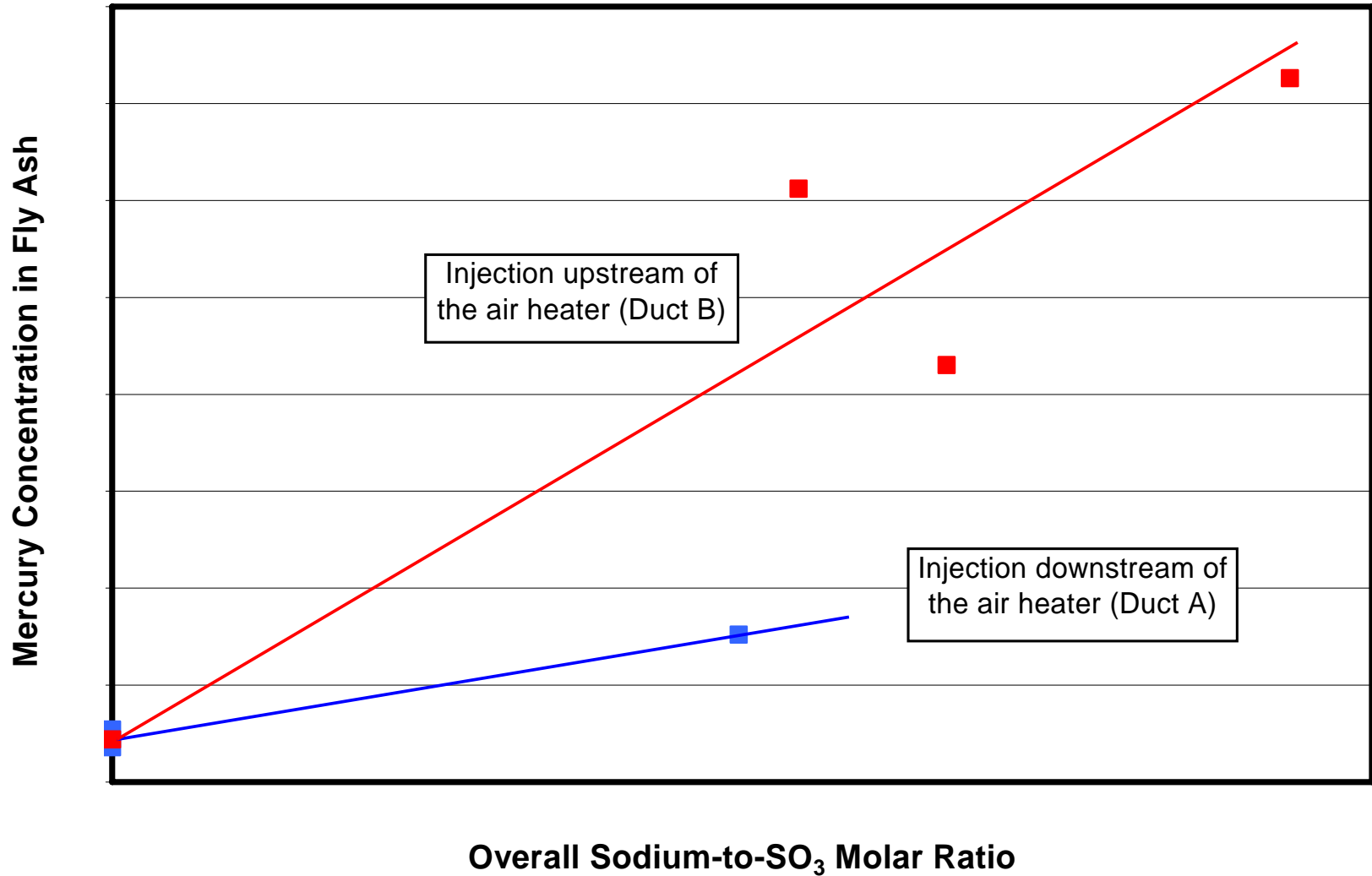
Green Trend = Evaporation Temperature, °F (NaBS Fouling Conditions)

Blue Trend = SCR NO_x Out (ppm)

Impact of SO₃ on Hg Capture in Ash



Mercury Co-Removal Results



Near-Term Performance Evaluation

- Operate Duct 5B System & Monitor Overall Performance
 - Longer-term air heater fouling experience
 - NO_x removal efficiency
 - ✖ Operation at elevated ammonia slip
 - Lance reliability & required maintenance
 - BOP impacts
 - Catalyst activity
 - Costs & benefits
- Relocate Duct 5A Injection Location (in Progress)
- Relocate Units 1 - 4 Injection Locations (Future)

Pre-SCR Summary

- SO₃ Removal Upstream of the SCR:
 - Greatest potential for benefits & cost savings
 - Pre-SCR SBS installed on 6 units (3,700 MW)
 - Operating experience is accumulating
- Test Results at Gibson are Promising
 - SO₃ levels at the SCR inlet are < 1 ppm
 - ✖ Provides significant MOT benefit
 - SO₃ levels at air heater inlet are < 5 ppm
 - ✖ Should reduce air heater fouling relative to historical levels
 - ✖ Enhanced mercury co-removal with fly ash
 - ✖ Other benefits such as enhanced NO_x removal are possible

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Liquid Injection Discussion

- Advantages of Liquid Injection
- Challenges of Liquid Injection
- Actual Operating Experience

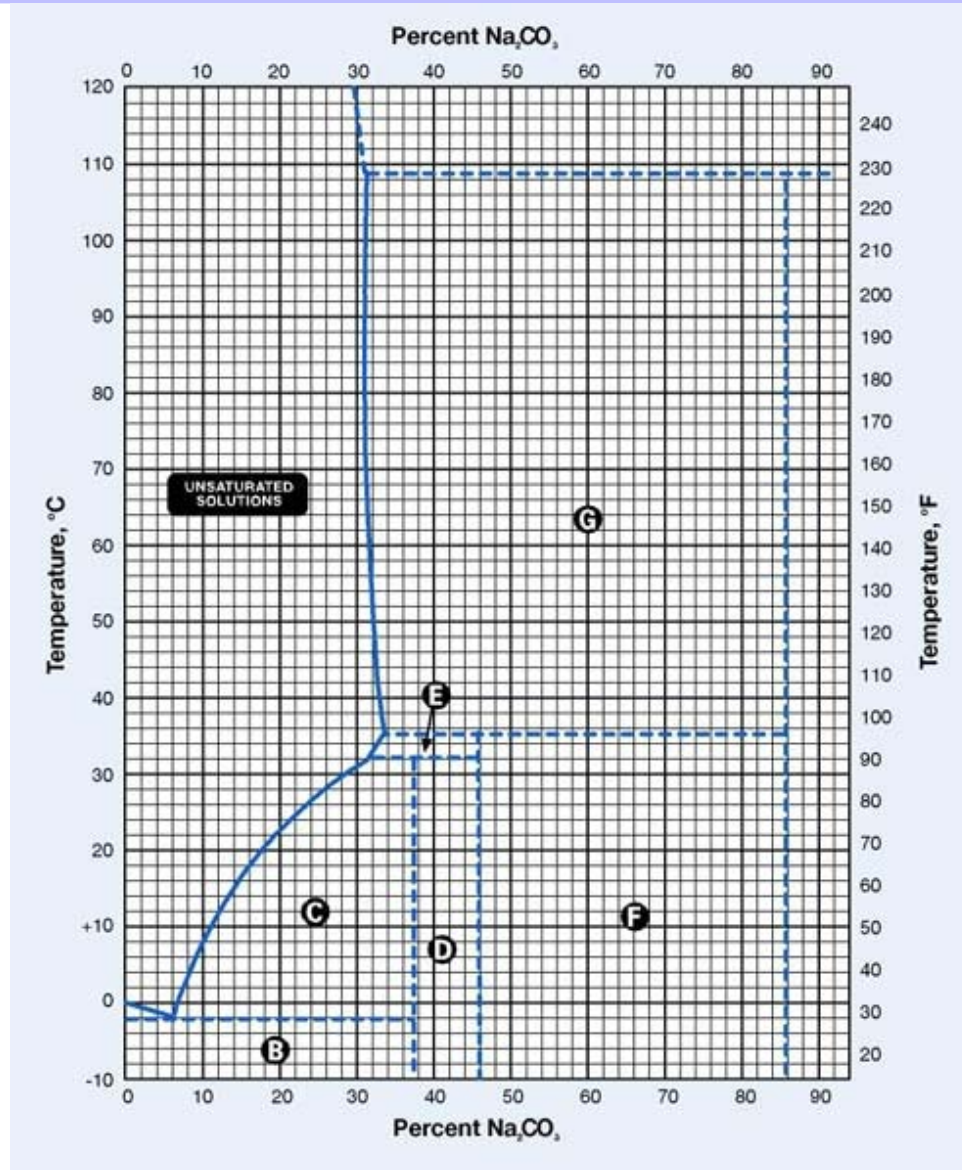
Advantages of Liquid Injection

- Precise Control of Liquid Flow Rates and Reagent Distribution in Flue Gas
- Ultra-Fine Droplet Atomization
 - Dual-fluid air atomizing injection nozzles
 - Rapid drying time
- Dried Reagent Particle Size is Extremely Small
 - Actual reagent particle size is optimal for reaction, ranging from 1-10 μ
 - Higher reagent surface area and bulk particle density resulting in excellent SO₃ removal at low sodium to SO₃ injection ratios and lower reagent operational costs

Challenges of Liquid Injection

- Sorbent Solubility
- Injection Lance Deposition
- Internal Duct Deposition

Sodium Carbonate Sorbent Solubility



Elevated Storage and Delivery Requirements

- Issue:

- Sodium based solution is a clear liquid. The sodium salts will precipitate from solution at lower temperatures (32° - 100°F) depending on concentration

- Design Approach:

- Immersion tank heaters; insulated and heat-traced process lines
- Alarms and interlocks associated with equipment and operation to minimize potential of precipitation

Precipitation Examples



Injection Lance Maintenance Requirements

- Issue:

- Periodic injection lance deposition can affect nozzle and system performance.

- Design Approach:

- Engineering design measures:

- ✘ Each individual injection lance has both a local flow indicator and remote transmitter. The PLC/DCS has alarms and interlocks to notify operators of injection lances with flow rates out of the expected range

- Utility operation and maintenance measures:

- ✘ Utility to regularly extract and inspect each lance (recommended once every two weeks initially and monthly for long-term operation)
- ✘ Utility to promptly service any injection lance showing abnormal flow

Actual Operating Experience – Problematic Nozzle Deposition



Actual Operating Experience – Optimal Nozzle Inspection



Internal Duct Deposition

- Issue: Deposits Can Form Inside of Duct
- Three Causes of Deposition:
 - Wet impingement of injected reagent
 - Injection lance and nozzle deposition
 - Sodium bisulfate formation

Internal Duct Deposition

- URS' Engineering Design Measures:
 - Computational Fluid Dynamics (CFD) model executed during initial design phase to optimize nozzle placement, reagent distribution, and determine required duct modifications
 - Strict quality control on all nozzle components and injection lances. All injection lances are rigorously tested prior to installation
 - Interlocks and alarms programmed into control logic to minimize potential deposition
 - Detailed training and hands-on maintenance demonstrations to minimize human error
 - Optimal injection molar ratio based on typical unit operating conditions and previous SBS Injection system performance data

Internal Duct Deposition

- Utility's Operation and Maintenance Measures:
 - Prompt servicing of any injection lance showing abnormal flow
 - Regular extraction and inspection of each lance (recommended once every two weeks initially)
 - Regular duct inspections during outages
 - Typical process data monitoring over time (e.g., pressure drops, flue gas balance, etc...)

Actual Operating Experience – Case Study: Internal Duct Deposition – 2004



Actual Operating Experience – Case Study: Internal Duct Deposition – 2005



Actual Operating Experience – Case Study: Internal Duct Deposition – 2006



Conclusions

- Liquid Injection Has Advantages:
 - Precise control of liquid flow rates and reagent distribution
 - Ultra-fine droplet atomization
 - Extremely small dried reagent particle size
- Liquid Injection Has Challenges
 - Sorbent Solubility
 - Injection lance deposition
 - Internal duct deposition
- Challenges can be managed successfully as shown in multiple operating utilities. Successful system functionality requires significant initial design experience and a utility's commitment to proper operation and maintenance.